Suggested Practical Assignments for a course on Robotics using *RoboAnalyzer* software

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As a part of a one semester introductory course on robot geometry and mechanics, the following assignments may be prescribed for the students using the RoboAnalyzer software. This may cover almost a typical semester of 14 weeks. Three weeks may be utilised to take presentations from the students, based on what they learned, or presentations on projects as a part of the course.

Course Structure: 14 Weeks, One session per week (~2 hours).

Textbook: Introduction to Robotics by S. K. Saha (2nd Edition, McGraw Hill Higher Education, New Delhi, 2014).

Software: RoboAnalyzer (V.7.1) downloaded from www.roboanalyzer.com (Free for Academic Use)

The possible assignments are outlined in Table I. This gives a summary of the hands-on tasks on relevant topics in robot mechanics. The prerequisites and chapters in the textbook would provide the related theory. Hence prior reading of the related chapters would be helpful for enjoyable sessions.

TABLE I   LIST OF PRACTICAL ASSIGNMENTS

Week	Practical Assignments using RoboAnalyzer	Topics Covered	Textbook Sections
1	Introduction to RoboAnalyzer	Usage of RoboAnalyzer	Appendix C
2	Virtual Models of Industrial Robots	Industrial Robots	Chapter 2, Appendix C
3	Understanding coordinate frames and transformations	DH Parameters, Robot Geometry	Chapter 5, Appendix A
4	Forward kinematics of robots	Robot Kinematic Analysis	Chapter 6
5	Inverse kinematics of robots	Robot Kinematic Analysis	Chapter 6
6	Case Study: Kinematics of MTAB Mini Robot	Robot Kinematic Analysis	Chapter 6
7	Case Study: Workspace Analysis of a 6 axis robot	Workspace Analysis	Chapter 6
8	Inverse and Forward dynamics of robots	Robot Dynamics	Chapter 8*
9	Creating robot joint trajectories	Trajectory Planning	Chapter 12
10	Application: Writing a welding profile using a virtual robot	Cartesian Motion of Industrial Robots	Chapter 2, 12
11	Application: Control a virtual robot using a joystick	Industrial Robots	Chapter 13

*This assignment also corresponds to the topics covered in Chapter 9 (for advanced learners only).

Instructions: The instructors should read the user manual and familiarise themselves with the RoboAnalyzer software, and are expected to be conversant with the relevant topics provided in the chapters of the book (mentioned in Table I).

The remaining weeks can be utilised to take presentations from the students on what they have learned or presentations on some projects as a part of the course. Table II gives a list of suggested topics for projects and presentations.

TABLE II   LIST OF SUGGESTED PROJECTS

S. No.	Projects	Description	Duration	Estimated time to be spent
1	Visualization and identification of DH parameters of an industrial robot.	The students must select a commercial wrist partitioned industrial robot and download the data sheet / technical drawing of the robot from the manufacturer's website*. Making use of the same, the DH parameters must be determined and the skeleton model of the robot must be visualized in RoboAnalyzer.	2 weeks	15 hours
2	Kinematic analysis of MTAB Aristo Robot	The students must perform the forward and inverse kinematic analyses of the MTAB Aristo robot (6-DOF) using the concepts in Chapter 6 of the textbook. MATLAB# program may be prepared to generate and verify the results of kinematic analysis.	3 weeks	20 ours

*For e.g.: http://www.kuka-robotics.com/res/sps/f776ebab-f613-4818-9feb-27612db8dc4_PF0011_KR_5_arc_en.pdf
MATLAB software must be installed in the user's computer to do this analysis.

Overview of Tasks for Practical assignments mentioned in Table I

1.   Introduction to RoboAnalyzer
Tasks:
-   Study the RoboAnalyzer software, its features and its functionalities.
-   Familiarise with the GUI.
-   Load and visualize skeleton and industrial robots.

2.   Virtual Models of Industrial Robots
Tasks
-   Familiarise students with commonly used six-axis robots.
-   Use Virtual Robots Module to study about the robot details (like joint limits, payload, etc.). Note down the details for future reference.
-   Demonstrate joint-level and Cartesian-level motions of robots in Virtual Robots Module.

3. Understanding Coordinate Frames and Transformations

Tasks
- Load a robot model and visualize the Denavit-Hartenberg (DH) parameters.
- Create a skeleton robot model for a given set of DH parameters specified by the instructor.
- Calculate the transformations between the coordinate frames in the skeleton model. Verify it in RoboAnalyzer (and MATLAB, optionally).

4. Forward Kinematics of Robots
Tasks
- Forward kinematics of a 2-DOF planar robot
  - o Perform the forward kinematics of the 2-DOF planar robot of given DH parameters using RoboAnalyzer.
  - o Visualize the motion and plot the values of the end-effector coordinates.
  - o Calculate the end-effector position for a given set of joint values, using transformation matrices and verify with RoboAnalyzer.
- Forward kinematics for a 3-DOF anthropomorphic arm and a 3-DOF wrist
  - o Perform the forward kinematics for a 3-DOF anthropomorphic arm and a 3-DOF spherical wrist using RoboAnalyzer.
- Forward kinematics of KUKA KR5 Arc Robot
  - o Perform the forward kinematics from a given joint configuration to another. Visualize the results.

5. Inverse Kinematics of Robots
Tasks
- Inverse kinematics of a 2-DOF planar robot
  - o Perform the inverse kinematics of a 2-DOF planar robot of given DH parameters using RoboAnalyzer.
  - o Derive the analytical expressions for the inverse kinematics problem of the 2-DOF planar robot using the formulas given in the textbook and verify the solutions obtained in the above step.
  - o Visualize the motion and plot the values of the end effector coordinates.
- Inverse kinematics for a 3-DOF anthropomorphic arm and a 3-DOF wrist
  - o Perform the inverse kinematics for a 3-DOF anthropomorphic arm and a 3-DOF spherical wrist using RoboAnalyzer.
- Inverse kinematics of KUKA KR5 robot

o Perform the inverse kinematics of KUKA KR5 Arc robot for a given end-effector position and orientation using RoboAnalyzer.
o Verify that all possible solution give the correct end-effector pose.
o Visualize and understand the multiple solutions for inverse kinematics.

6. Kinematics of MTAB Mini Robot

Tasks
- Apply the concepts from practical assignments 4 and 5 in Table I to perform the forward and inverse kinematics of MTAB Mini robot.
- Simulate the robot in RoboAnalyzer and Virtual Robots Module.
- Find out more about the Mini robot and its specifications from the website of MTAB. (http://www.mtabindia.com/robotics/minirobotrobotics.htm)

7. Workspace Analysis of a 6 axis Robot

Tasks
- Select a 6-axis industrial robot and download its data sheet from the relevant website.
- Demonstrate the concept of workspace boundary.
- Plot rough workspace boundary using RoboAnalyzer/Virtual Robots Module.
- Presentation on workspace of different robot architectures (optional).
- Familiarise students to understand robot workspace from industrial robot manuals (optional).

8. Inverse and Forward Dynamics of Robots

Tasks
- Perform the inverse dynamics for a planar and spatial robot. Investigate the change in torque when the inertia properties and/or DH parameters are changed.
- Change the input joint trajectory and investigate the effect on required joint torques.
- Perform the forward dynamics for a planar and spatial robot.

9. Creating Robot Joint Trajectories

Tasks
- Study the various joint trajectory schemes and observe the motion of the joints for each trajectory schemes and their plots with time. Prepare a comparison table.
- Verify the results in RoboAnalyzer and with those obtained using a program based on a different programming language (say, MATLAB, MS Excel, C++, etc.).

10. Writing a Welding Profile using a Virtual Robot

Tasks
- Calculate a welding profile (which may be simple a capital alphabet, say, 'A') using graph sheet.
- Verify that the profile is inside the robot's workspace.

- Move the end effector using the calculated points in Cartesian space and generate the profile using end-effector trace.

11. Control a Virtual Robot using a Joystick
Tasks
- Use a joystick device to control an industrial robot's motion. The students can be asked to move the robot in a particular pattern.
- Demonstrate joint-level and Cartesian-level motion of the robot.
- Brief understanding of teach pendants and other devices to interact with a robot.

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